Concept Mapping: Connecting Educators
Proc. of the Third Int. Conference on Concept Mapping
Tallinn, Estonia & Helsinki, Finland 2008

CONCEPT MAPS AS MEANINGFUL LEARNING TOOLS IN A WEB–BASED CHEMISTRY MATERIAL

Johannes Pernaa & Maija Aksela
Chemistry Education Center, Department of Chemistry, University of Helsinki, Finland
E-mail: johannes.pernaa@helsinki.fi

Abstract. This paper presents a web-based learning material and its design process which goal is to support meaningful chemistry learning in the context of insect chemistry through concept maps. This material was designed based on the results of a four phases of a design research process: (i) a theoretical problem analysis phase, (ii) a development of a material phase, (iii) an evaluation phase, and (iv) a further development phase. This material was found useful primarily for high-school chemistry instruction. The results show that concept maps were an effective learning aid and navigation tool in web-based learning environment, according to chemistry teachers.

1 Introduction

It is often difficult to find relevant information from web pages. A traditional web material that consists of large numbers of web pages can sometimes be difficult to use for educational purposes. Students may find the structure of the material unclear. In addition, the structural complexity also affects learning motivation, which is inconsistent with Ausubel's theory of meaningful learning (Ausubel, 1968).

Using ICT in chemistry education is still rather infrequent at the basic level in Finland and also globally (Meisalo et al., 2007). Especially, chemistry teachers wish more useful web-page materials. Web materials offer several ways to support meaningful chemistry learning, for example, new opportunities to increase communication and interaction among students, more ways to seek and share scientific information, new kinds of educational materials and tools, which are also easy to bring into the classroom via the web (Aksela, 2005).

This material was created primarily for high-school chemistry teachers in Finland through a design research process (Edelson, 2002). The material has been partly translated to English (a goal is converting it entirely to English). The material approaches chemistry from an insect chemistry context, particularly semiochemicals, pigments, and honey bee that is a full of interesting chemistry.

2 Concept maps in chemistry

Chemistry is often full of abstract concepts, resulting from the complex nature of this science. It may lead to extensive misconceptions among students (Gabel, 1999). It is also a common problem in chemistry that even if students do well in examinations, they still may fail in solving basic textbook problems, which is a sing of rote learning (Pendley et al., 1994).

It is important to find various interesting ways that can lead toward meaningful chemistry learning. One way to accomplish this, is to apply Ausubel's theory of meaningful learning. Concept maps were devised as a device of meaningful learning, which can be regarded as the opposite of rote learning. Concept maps are graphical teaching, learning, evaluation and presentation tools (Novak 1998; Novak & Gowin, 1984).

In chemistry, the use of concept maps has been widely investigated. According to several studies (e.g. Cardellini, 2004; Francisco et al., 2002; Markow & Lonning, 1998; Nicoll et al., 2001; Osman Nafiz, 2008; Pendley et al., 1994; Regis et al., 1996; Stensvold & Wilson, 1992), concept maps help chemistry learning both in classrooms and in laboratories. According to Francisco et al. (2002) and Nicoll et al. (2001), concept maps are a useful learning tool in chemistry. Concept maps can improve understanding of chemical concepts and help build connections among abstract concepts. Concept maps can also be used as a misconception-correction tool. Concept maps bind concepts with linking words that help students see connections among them and organizes the knowledge hierarchically, based on scientific knowledge. (Francisco et al., 2002; Nicoll et al., 2001)

Markow & Lonning (1998) and Osman Nafiz (2008) studied the use of concept maps in laboratory activity. They both reported that pre- and post-laboratory concept maps made easier for students to understand concepts related to the laboratory work. Sometimes those concepts remain unconnected, because the laboratory work itself demands much concentration. (Markow & Lonning, 1998; Osman Nafiz, 2008). There is also evidence that concept maps reduce students' attentions to distractions in laboratory and improve understanding of procedures and directions used in the laboratory work. (Stensvold & Wilson, 1992)

3 Concept maps in web materials

Traditional web pages are the major technique used for organizing information and browsing in the internet. Traditional web pages are often just printed pages, which can be difficult to organize if web materials consist of large number of pages. When the content of the material is hierarchical, concept maps offers a meaningful and efficient way to organize the information (Carnot et al., 2001).

Little research has been conducted to investigate how concept maps work as navigational and learning tools in a web-based learning environment. Earlier study (Carnot et al., 2001) made from the area focused on comparing searching results between traditional web pages and concept hyper maps. The study covered searching efficiency and searching accurancy. It also took into account differences between meaningul and rote learners. According to study, both meaningful and rote learners attain better searching outcomes and searching efficiency through concept hyper maps, but meaningful learners gain a little more benefit from concept maps than rote learners. (Carnot et al., 2001)

4 Design research

This study was conducted as a design research (Edelson, 2002). The main research question is: *What kind of a web-based learning environment can best support meaningful chemistry learning through concept maps?*

The research consisted of four phases: (i) a theoretical problem analysis through a literature analysis, (ii) a development of material phase, (iii) an evaluation phase, and (iv) further development of the material. The purpose of the evaluation phase was to investigate how concept maps can serve as a component of web-based material.

As a part of theoretical problem analysis a literature analysis by using a content analysis was proceeded. It included 24 Finnish high-school chemistry text books. After the results of the literature analysis, the content of the material was limited to semiochemicals, pigments and one insect example (honey bee).

The material was designed according to Jonassen's (1999) criterions on meaningful web-based learning environment. The material includes contextual, constructive and active features. The objective to produce an extensive insect chemistry material bank for meaningful learning purposes was kept in mind at all times.

Evaluation was executed in the autumn 2007. Research sample consisted of 17 experienced chemisty teachers. Questionnaires were delivered to respondents. They had time to acquaint oneself with the material and fill up the forms. 76 % of the teachers had been teaching over 15 years. 59 % of the teachers found generally working in the web-based learning environment pleasant (see Table 1). Most of them thought, that also students enjoy working in web. Teachers opinions towards concept maps were more divided. Only 18 % used concept maps as teaching tools, 41 % used concept maps as learning tools and 65 % of the teachers thought that concept maps improve learning.

Proposition	Answer (%)		
Working in a web-based learning environment is pleasant.	Pleasant	Unpleasant	Can't say
	59	0	41
I think students enjoy to study in a web-based learning environment	Pleasant	Unpleasant	Can't say
	76	0	24
I use a web-based learning environment	Often	Seldom	Never
	35	47	18
I use web-based materials in my teaching.	Often	Seldom	Never
	35	59	6
I use concept maps as teaching tools.	Often	Seldom	Never
	18	58	24
I use concept maps as learning tools.	Yes	No	Can't say
	41	41	18
Concept maps improve learning.	Yes	No	Can't say
	65	0	35

Table 1. Chemistry teachers answers, % (N=17).

The results of the evaluation were analyzed. Further developments were made based on the results and feedback. The final material is available online at http://www.helsinki.fi/kemia/opettaja/aineistot/hyonteistenkemiaa/index.htm (in Finnish).

5 Results

5.1 The designed Web material

The idea was to design the structure of the web material to support meaningful chemistry learning through an easy navigation process. The solution was to create the navigation system from concept maps. The concept maps were made by *CmapTools* program (see http://cmap.ihmc.us). The *CmapTools* program was selected, because it enables, for example diverse link resource possibilities, example animations, pictures and documents. The student navigation process is restricted by links, which makes it impossible to get lost in the material.

The web material consists of four map pages (see Figure 1 and Figure 2), eight concept map pages (see Figure 3) and 11 web pages (see Figure 4). The map pages help students sketch the structure of the material and form the basic navigation routes. Navigation is restricted to one branch (semiochemicals, pigments, bees or tasks) at a time (see Figure 1 and 2), which helps students navigation and orginizes extensive material.

The level of information in insect chemistry becomes deeper after every stage. A concept map page (see Figure 3) gives an example to the content of the web page (see Figure 4). The purpose of the concept map page is to help students to preorganize the knowledge of the web page. Concept maps provide students a challenge to construct their own mental models from the content of the upcoming web page. Concept map pages can also be suitable for fast recap during the returning from the web page level, where the chemistry level is deepest. Making the learning easier for students, web pages include animations and several interactive molecular models, which help students to understand the chemical phenomena in question.

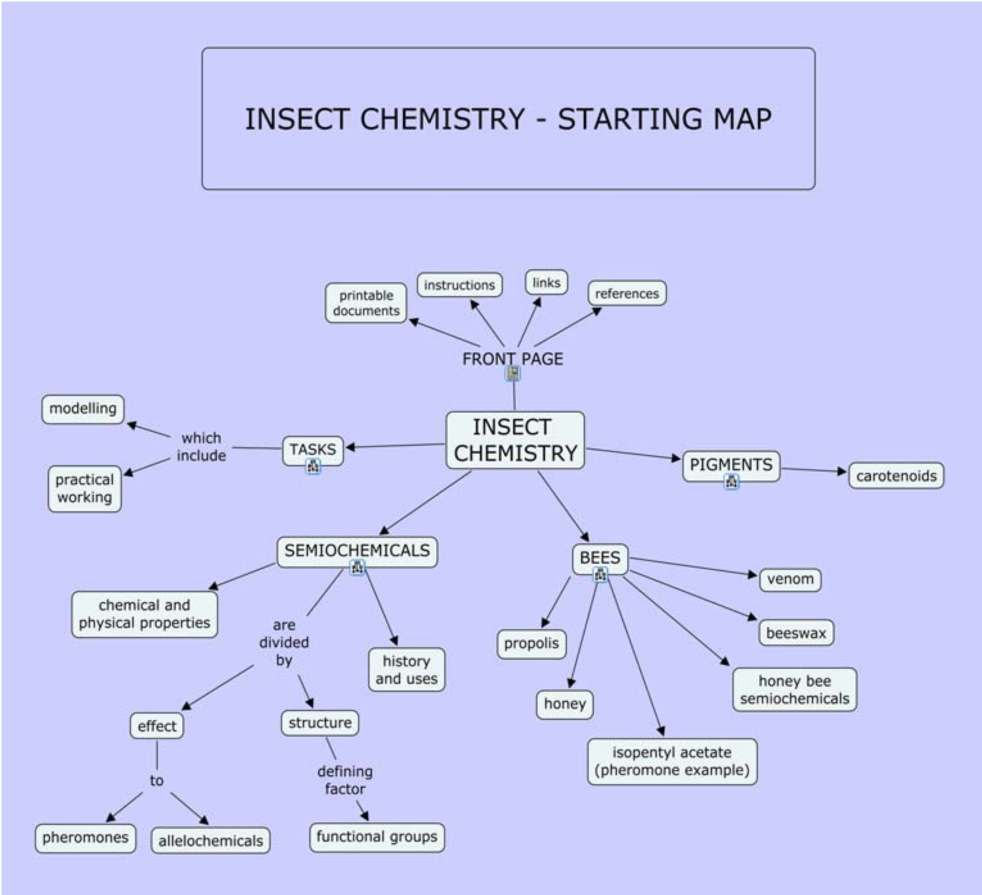

Figure 1. A Starting map of Insect chemistry (a table of contents).

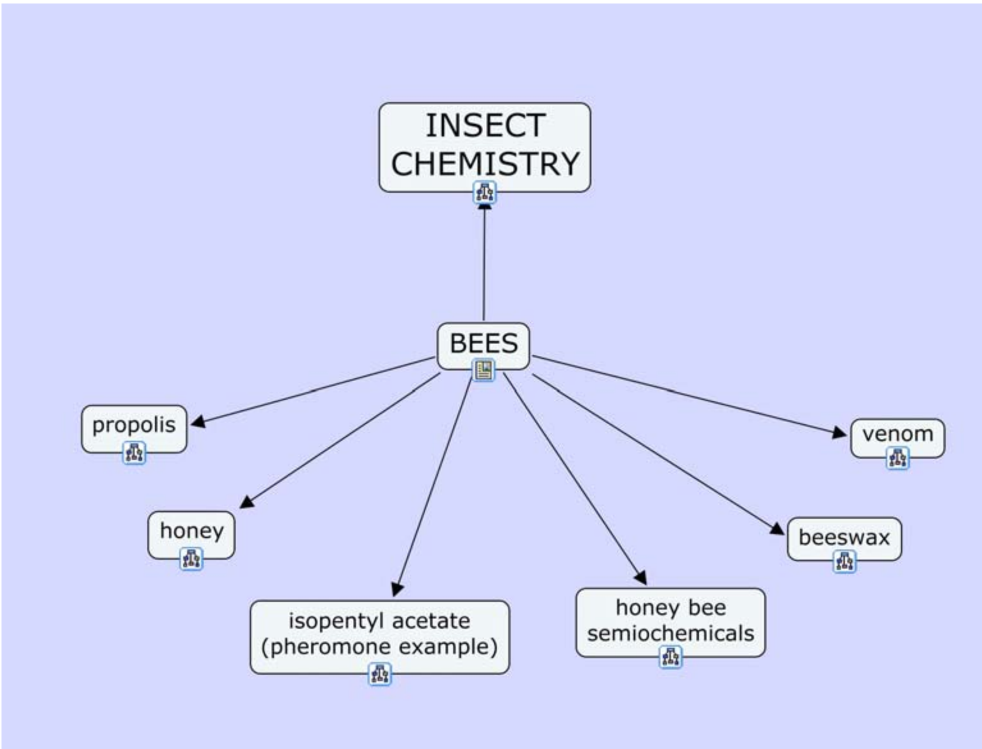

Figure 2. A Map page of Bees.

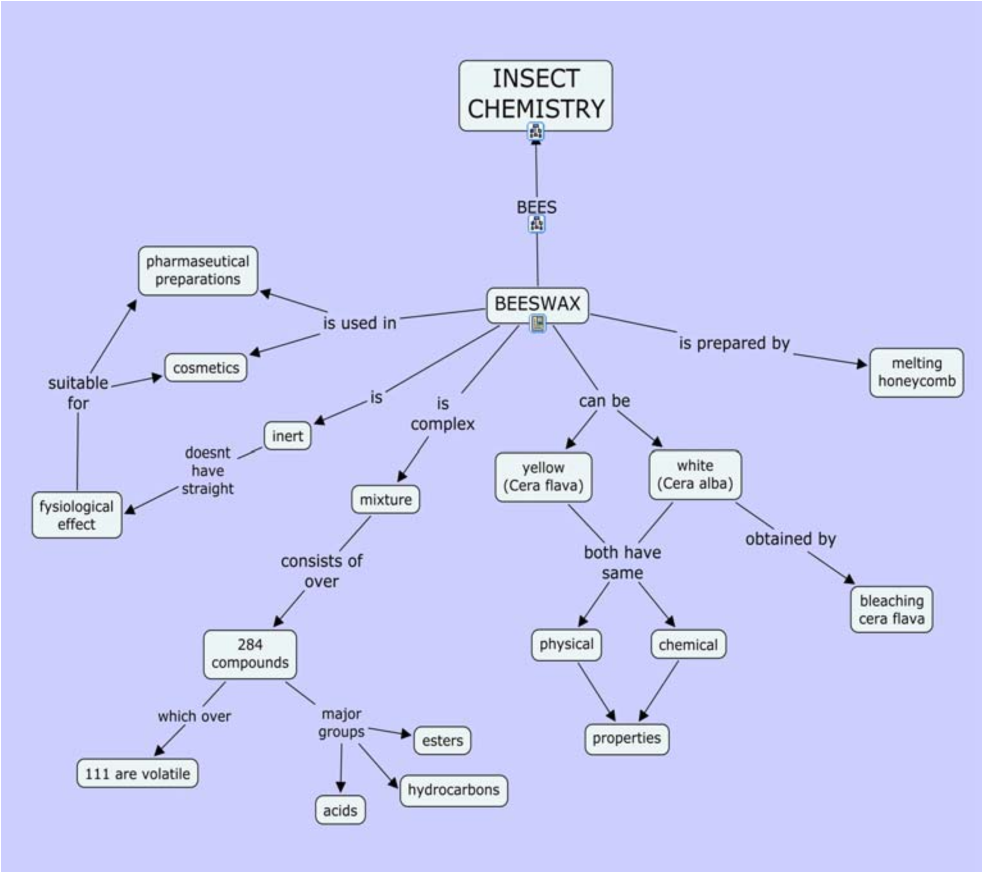

Figure 3. A Concept map page of Beeswax.

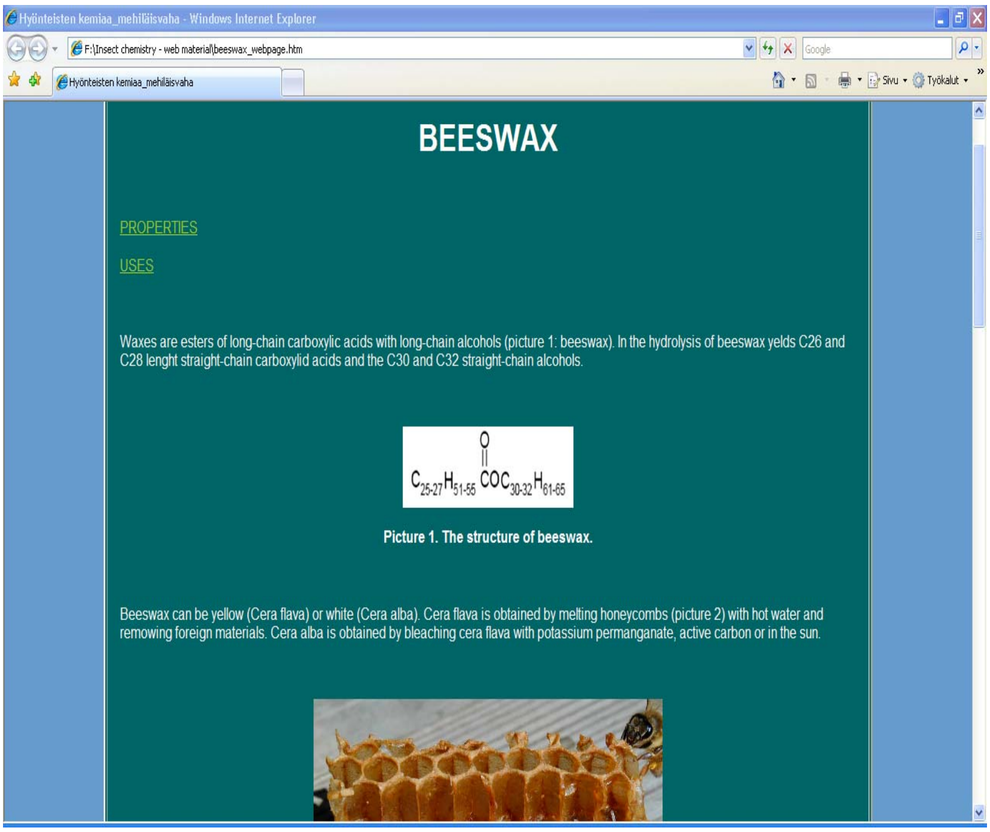

Figure 4. A Web page of Beeswax.

5.2 The results of evaluation phase

The material was evaluated using a five-point Likert scale (1=bad, 2=fair, 3=adequate, 4=good and 5=excellent).

The material was useful among the chemistry teachers. All averages for questions are quite high (see Table 2). According to 71 % of the teachers (at least good (=4) in the Likert scale) the used concept maps clarified the structure of the material (average 3,8). 18 % of the teachers (1 or 2 in the Likert scale) felt that the material was too extensive and there were too much concept maps. 88 % of the respondents felt that the concept maps made the learning more efficient (4 or 5 in the Likert scale).

However, concept maps' usability as a navigation tool divided opinions. Overall, the respodents felt that the *Cmap* hyper maps were a suitable navigation tool (average 3,6), but almost 18 % (1 or 2 in the Likert scale) felt that the Cmap hyper maps were difficult to navigate. 18 % felt that the two clicks, which are needed to perform in order to get through the link resources, was an unsatisfactory feature and made the navigation difficult.

Question	**Frequency**					**Average**
	1	**2**	**3**	**4**	**5**	
How do concept maps effect to the structure in the topic?	1	2	2	6	6	3,8
How do concept maps work as a learning tool?	0	0	2	10	5	4,2
How do concept maps work as a navigation tool?	1	2	3	7	4	3,6

Table 2. Results of the evaluation phase, (N=17).

Some open comments of the teachers:

Positive:

- *"The system is clear and educational."*
- *"Versatile, clear and easy to navigate."*
- *"I feel like the learning becomes more effective."*
- *"Practical and interesting way to organize knowledge"*
- *"Concept maps clarified the structure"*

Negative:

- *"There were too much concept maps. I did not get the whole picture."*
- *"Cmap page is difficult to navigate."*
- *"The material is difficult to use just in chemistry teaching because of the biological side. Maybe it is also too extensive."*
- *"Concept maps have a bad reputation."*
- *"There is too much concept maps and too little time to explore the material."*

6 Summary and conclusions

A useful web-based learning material to support meaningful chemistry learning in the context of insect chemistry through concept maps was designed. Overall, the material was well accepted among the respondents. 71 % of the chemistry teachers felt that concept maps clarified the structure of the material, and 65 % replied that concept maps are an excellent or a good navigation tool for web material. Also Carnot et al., (2001) reported that hyper concept maps are a proper browsing and knowledge organizing tool in www environment.

Only 18 % felt that concept maps are not a suitable navigation tool for web material. Negative freedback concerning the browsing aspects considered about hyper cmaps made with *CmapTools* -program. Some of the teachers found them hard to use because of the double clicks, which are needed to perform in order to get through the link resources. But then, double clicks are a part of the programs diverse link resource properties, which influenced to the program selection in the first place.

During the answering process, chemistry teachers' opinions towards concept maps changed. Before getting familiar with the material, only 65 % thought that concept maps improve learning. After working with the material, 88 % of the teachers felt that concept maps made chemistry learning efficient (4 or 5 in the Likert scale). Results correlates with other researches made from the same area (e.g. Cardellini, 2004; Francisco et al., 2002; Markow & Lonning, 1998; Nicoll et al., 2001; Osman Nafiz, 2008; Pendley et al., 1994; Regis et al., 1996; Stensvold & Wilson, 1992).

The small sample size (N=17) is a weakness in this study. It is also notable that some of the respondents felt that the material was too extensive for full exploring and evaluation. But then, the material was supposed to be extensive because the objective of the material was to serve as an extensive and diverse insect chemistry material bank for chemistry teachers.

In the future, it is important to develop the material more through research. It is important to study how teachers use the material, and how students experience on it. There should also be studied, how the material supports meaningful chemistry learning. The content of the material can also be limited in a way so, that it can be used as teaching material in high schools for a specific chemistry area. According the literature analysis, the area could be for example organic chemistry related to semiochemicals. It is important that the content fits under the goals of the the Finnish curricula. At this point, the results are encouraging and it justifies further studies in this area.

7 Acknowledgements

We thank Prof. Ilkka Kilpeläinen for his guidance concerning the chemistry content of the material and Prof. Mauri Åhlberg for his critical feedback of the research.

References

Aksela, M. (2005). Supporting Meaningful Chemistry Learning and Higher-order Thinking Through Computer-Assisted Inquiry: A Design Research Approach. Chemistry Education Center Department of Chemistry University of Helsinki Finland.

Ausubel, D. P. (1968). Educational psychology: A cognitive view. New York: Holt, Reinehart and Winston.

Carnot, M. J., Dunn, B., Cañas, A. J., Graham, P. & Muldoon, J. (2001). Concept Maps vs. Web Pages for Information Searching and Browsing. Manuscript in preparation. Institute for Human and Machine Cognition.

Cardellini, L. (2004). Conceiving of Concept Maps To Foster Meaningful Learning: An Interview with Joseph D. Novak. Journal of Chemical Education, 81(9), 1303-1307.

Edelson, D. C. (2002). Design research: What we learn when we engage in design. The Journal of the Learning Sciences, 11, 105-121.

Francisco, J. S., Nakhleh, M. B., Nurrenbern, S. C. & Miller, M. L. (2002). Assessing Student Understanding of General Chemistry with Concept Mapping. Journal of Chemical Education, 79(2), 248-257.

Gabel, D. (1999). Improving Teaching and Learning through Chemistry Education Research: A Look to the Future. Journal of Chemical Education 76 (4), 548-553

Jonassen, D. H. (1999). Designing constructivist learning environments. In C. Reigeluth (Ed.), Instructional design theories and models: A new paradigm of instructional theory (volume II, pp. 215-239). Mahwah, NJ: Lawrence Erlbaum Associates.

Markow, P. G. & Lonning, R. A. (1998). Usefulness of Concept Maps in College Chemistry Laboratories: Students' Perceptions and Effects on Achievement. Journal of Research in Science Teaching 35(9), 1015–1029.

Meisalo, V. Lavonen, J., Juuti, K. & Aksela, M. (2007). Information and communication technology in school science in Finland. In Pehkonen, E., Ahtee M. & Lavonen J (Eds.), How Finns learn mathematics and Science. The Netherlands: Sense Publishers.

Nicoll, G., Francisco, J. S. & Nakhleh, M. (2001). An Investigation of the Value of Using Concept Maps in General Chemistry. Journal of Chemical Education, 78(8), 1111-1117.

Novak, J. D. (1998). Learning, creating, and using knowledge: Concept Maps as Facilitative Tools in Schools and Corporations. Mahweh, NJ: Lawrence Erlbaum Associates.

Novak, J. D., & Gowin, D. B. (1984). Learning How to Learn. New York: Cambridge University Press.

Osman Nafiz, K. (2008). A Student-Centred Approach: Assessing the Changes in Prospective Science Teachers' Conceptual Understanding by Concept Mapping in a General Chemistry Laboratory Research in Science Education, 38(1), 91-110.

Pendley, B. D., Bretz, R. L. & Novak, J. D. (1994). Concept Maps as a Tool To Assess Learning in Chemistry. Journal of Chemical Education, 71(1), 9-15.

Regis, A, Albertazzi, P. G, and Roletto, E. (1996). Concept Maps in Chemistry Education. Journal of Chemical Education, 73, 1084-1088.

Stensvold, M. & Wilson, J., T. (1992). Using Concept Maps as a Tool To Apply Chemistry Concepts to Laboratory Activities. Journal of Chemical Education, 69(3), 230-232.